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# 2

91156



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## Level 2 Biology 2022

### 91156 Demonstrate understanding of life processes at the cellular level

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of life processes at the cellular level.	Demonstrate in-depth understanding of life processes at the cellular level.	Demonstrate comprehensive understanding of life processes at the cellular level.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

**You should attempt ALL the questions in this booklet.**

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–15 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

**Excellence**

**TOTAL**

**24**

**QUESTION ONE: PHOTOSYNTHESIS**

All plants require specific reactants to start the process of photosynthesis.



Source: <https://www.doc.govt.nz/nature/native-plants/>

- (a) Describe the reactants required for photosynthesis AND how they enter the plant.

The reactants required for the process of photosynthesis are water and carbon dioxide. Water enters the plant through the root hair cells by osmosis. It travels into the plant's cells if they are hypertonic to the soil. The <sup>root hair</sup> cells then become hypotonic to other cells. Osmosis occurs between plant cells until water reaches the chloroplasts in leaf cells where photosynthesis occurs. Carbon dioxide enters by diffusing through the stomata when open if the concentration of  $\text{CO}_2$  is lower in the leaf than cells than outside in the environment.



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- (b) Photosynthesis takes place inside the chloroplasts. The main structures involved in photosynthesis are: the outer membrane, inner membrane, stroma, thylakoid membrane, and grana.



Adapted from: [www.mcqbiology.com/2013/04/multiple-choice-questions-on-chloroplast.html](http://www.mcqbiology.com/2013/04/multiple-choice-questions-on-chloroplast.html)

Discuss how specific reactants in the light-dependent and light-independent reactions affect the amounts of the products of photosynthesis:

In your answer:

- describe the function of TWO named structures from the chloroplast diagram
- explain how the structures of the chloroplast are built to help them carry out their function
- discuss how the structures of the chloroplast work together to carry out the process of photosynthesis.

Photosynthesis is the series of enzyme controlled reactions that, when light is absorbed by the chlorophyll, converts  $\text{CO}_2$  and  $\text{H}_2\text{O}$  into glucose with  $\text{O}_2$  as a by-product. Photosynthesis occurs in the chloroplasts of plant cells. These are cell organelles that are oval in shape and have adaptations like a double membrane, thylakoids arranged into grana, and stroma. The thylakoids are arranged into stacks of grana to carry out their function in the light dependent stage of photosynthesis. The thylakoids are shaped like flattened disks which gives them a greater surface area in comparison to their volume. The thylakoids are arranged in grana to further increase their surface area. The high surface area is important because the light dependent reactions occur

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on the thylakoid membranes. A large surface area to volume ratio increases the rate of reaction because there is a larger surface so more reactions can occur simultaneously where water is split to produce  $H^+$  and  $O_2$ . The chlorophyll where light energy is absorbed and converted to the energy carriers ATP and NADPH are also located in the thylakoid membranes. A greater surface area allows more chlorophyll, which means more light energy can be absorbed. As more light is absorbed the rate of photosynthesis will be high during hours with high light availability (daylight hours) unless factors like  $CO_2$  or water availability are low in concentration and become limiting. The structural adaptation of the stroma ~~is~~ allows the rate of photosynthesis ~~the~~ to be maximised. The stroma is a clear, enzyme rich fluid within the chloroplast. It is clear to allow light to easily pass through to the chlorophyll where it is absorbed which keeps the rate of reaction high. The stroma has a high concentration of enzymes because the photosynthesis process is controlled by the enzymes that catalyse each reaction. If there were less enzymes, fewer reactions could occur at once, which would limit the rate of reaction and therefore the rate of photosynthesis. The second stage, the light independent stage, occurs in the stroma. Here, using the energy carriers produced in the light dependent stage, carbon dioxide is fixed into glucose, the final product. If the stroma did not have enzymes within it, the final product could not be produced because enzymes catalyse the necessary reactions for its production. Therefore, by the stroma having many enzymes and being transparent, the amount of light absorbed and the rate of enzyme activity is maximised, which maximises the rate of photosynthesis.

However, the rate of photosynthesis can be limited if the



availability or concentration of reactants is low. Both water and  $\text{CO}_2$  are required for photosynthesis to occur because they are the two reactants. If the concentration of water is low, the amount of water that can be split in the light dependent stage to produce  $\text{H}^+$  for the energy carriers that are used in the light independent stage will also be low. This will affect the amount of carbon dioxide that can be fixed into glucose because, even if there is a high concentration of  $\text{CO}_2$ , the energy carriers are required for these reactions to occur. Likewise, if there is a high concentration of water but a low concentration of  $\text{CO}_2$ , there will not be optimal amounts of  $\text{CO}_2$  to fix, even if there are many energy carriers. This decreases the amount of glucose that is produced as a result.

Therefore, the factor in the lowest concentration directly limits the reactions of photosynthesis. If the rate of reaction is limited by one or more factor, the amount of glucose and  $\text{O}_2$  that is produced will also be limited. For optimal/maximum glucose production, there needs to be high concentrations of both reactants so that neither are limiting and instead, a factor like enzyme concentration or light availability is limiting.

For these reactions to occur, the structures of the chloroplast must work together. This is ~~clear~~ clear because the stroma is transparent to allow light to reach the chlorophyll and is enzyme-rich to catalyse both the light dependent and independent reactions. Additionally, the inner membrane is thin and semi permeable to allow  $\text{H}_2\text{O}$  and  $\text{CO}_2$  to rapidly ~~be transported in by osmosis and diffusion,~~ ~~diffuse in~~ and  $\text{O}_2$  to diffuse out. Rapid diffusion increases the concentration of reactants available at the chloroplast, which in turn maximises the rate of reaction and amount of glucose that is produced.

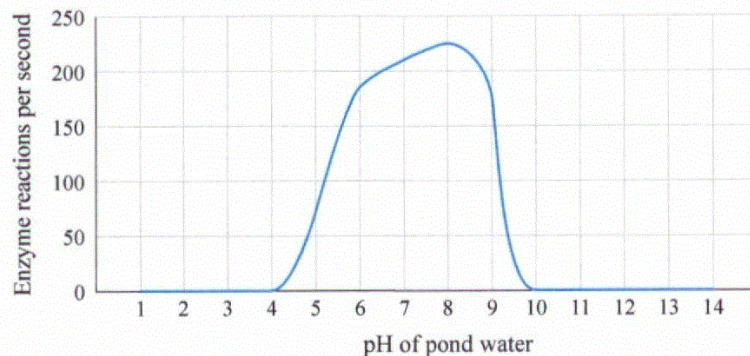


## QUESTION TWO: ENZYMES

Conditions of the water in a small pond can change throughout the day, and over a year. A change in pH can affect the rate of photosynthesis reactions. The presence of pollutants in the water can affect certain nutrients that are needed as co-factors for the enzymes involved in photosynthesis.

In an experiment to test the effect of pH on enzyme activity in *Elodea* cells, the following results were produced.

**Rate of *Elodea* enzyme reactions as a result of changing pH**



Adapted from: <https://pubmed.ncbi.nlm.nih.gov/20118304/>

- (a) Discuss the effects of pH and co-factors on enzyme activity in *Elodea* plants.

In your answer you should refer to the graph above and:

- describe the function of enzymes and their structure
- explain how co-factors affect enzyme activity
- discuss how and why pH affects enzyme activity in *Elodea*.

Enzymes are globular proteins that are made from chains of amino acids that are folded into a 3D structure. Enzymes have an active site which is where they catalyse reactions to build up or break down substances. They are of specific shapes so that only one type of substrate fits in the active site to form an enzyme-substrate complex and can therefore be catalysed. Their specific shape is due to hydrogen bonds and disulfide bridges holding the enzyme in shape. These bonds are between particular amino acids. Enzymes catalyse the reactions in the light ~~in~~ dependent and independent stages of photosynthesis of the *elodea* plant cells. Co-factors are nutrients or ~~organic~~ <sup>substances</sup> ~~molecules~~ that are required before certain reactions can occur with enzymes.



This is because co-factors bind to the active site, partially changing the active site's shape. This allows the substrate to fit and the reaction to be catalysed. If pollutants in the water mean the nutrients can no longer ~~that~~ act as co-factors, ~~cannot~~ the <sup>particular photosynthesis</sup> reaction with the enzymes they bind to will have a reduced rate or could stop if all of the nutrient cannot act as a co-factor. If any stage of photosynthesis is unable to occur at a fast rate because of a lack of <sup>required</sup> co-factors, the rate of the entire process will be negatively affected as all reactions must occur to successfully produce glucose (and  $O_2$ ). This means that enzyme activity in Elodea will reduce if the co-factors ~~cannot~~ are not available due to reacting with pollutants. This reduces the rate of photosynthesis, which reduces the production of glucose. This means Elodea may not grow as quickly because glucose is used ~~for~~ in respiration to produce energy for life processes like growth in plants. pH is another factor that affects enzyme activity. Enzymes have an optimum pH range where they function best. As shown on this graph, the optimum pH is 8 because the most enzyme reactions occur per second at this pH. Outside of this, the rate of ~~re~~ enzyme activity begins to slow. When enzymes experience pH levels outside their narrow optimum range (which is around 7.5 to 8.5 pH) ~~they begin~~ the hydrogen bonds and disulfide bridges holding the enzyme in its specific shape begin to break. The enzyme begins to unfold and is said to be denatured. As the shape of the active site is changed, they cannot fit their substrates to form an enzyme-substrate complex. Due to this, they cannot catalyse their reactions so the rate of enzyme activity is slowed. Slightly outside of the optimum pH

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range, the bonds only slightly break. If the enzyme returns to its optimum range, the bonds can reform meaning this decrease in enzyme activity is reversible. However, ~~too~~ extreme changes in pH break the bonds too much for them to reform, meaning enzymes are permanently inactive. This permanently affects the rate of enzyme activity. If pH conditions are changing in a pond, it is unlikely these pH changes will be extreme, so enzyme activity will be reduced or not optimal, but it will not have completely stopped. For this, ~~enzymes have to~~ the pH has to be less than 4 or greater than 10, which are significant changes. However, even with slight changes, if the rate of enzyme activity in Elodea ~~is~~ cells is slowed, this means the rate of the enzyme controlled process of photosynthesis will also be slower. Due to this, the production of glucose, and  $O_2$  as a by-product will be less, meaning there will be less glucose to be used as ~~at least~~ a reactant for respiration. Therefore, the Elodea will generate less ATP/energy for life processes if the pH <sup>of the pond</sup> is not at its optimum level of 8 pH.

Therefore, with the changing pH conditions in the pond, and with the presence of pollutants, enzyme activity and thus the rate of photosynthesis in the Elodea plants is rarely kept at optimum, meaning that respiration will also rarely be at optimum rate due to less glucose which is a reactant of respiration.



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### QUESTION THREE: CELLULAR RESPIRATION

Mosquito larvae come to the surface of the water and absorb oxygen through a breathing tube. When threatened, the larvae retreat to the bottom of the pond where they can absorb dissolved oxygen from the water.

Mosquito larvae are transparent, and it is possible to observe their hearts beating under a microscope. The number of heart beats per minute can be used as a way to measure the cell respiration rate of the heart cells, and to study the factors that affect it.



Source: [https://en.wikipedia.org/wiki/File:Culex\\_sp\\_larvae.png](https://en.wikipedia.org/wiki/File:Culex_sp_larvae.png)

- (a) Describe the purpose of cellular respiration.

To produce ATP/energy from glucose/food so that it can be used for cellular functions like metabolism, movement, growth, digestion and excretion.

- (b) As oxygen levels in the water decrease, respiration rate, and therefore heart rate decreases. Even when the water has NO oxygen left, the mosquito larvae's hearts could continue to beat.

	Heart beats per minute with changing dissolved oxygen concentrations in pond water				
Dissolved oxygen concentration (% saturation)	0	25	50	75	100
Number of heart beats per minute (bpm)	20	40	50	60	120

Discuss the observations above in relation to aerobic and anaerobic respiration, and their effect on the mosquito larvae's heart rates.

In your answer, refer to the data table and include:

- a description of where aerobic and anaerobic respiration take place in the cell
- an explanation of BOTH respiration processes that includes the materials required for each and their products
- elaborate on the possible effects on larval heart rate and type of respiration when exposed to 0% oxygen for more than a few hours.



~~Respiration is~~ Cellular respiration is the enzyme controlled process that ~~rete~~ breaks down glucose to produce ATP.

The process of respiration is separated into three stages.

Firstly, the glycolysis stage occurs in the cytoplasm of the cell.

Glucose is broken down to two pyruvate molecules. This releases two ATP. This is the only stage that occurs for anaerobic respiration if the oxygen availability is very low.

If no oxygen is available, pyruvate becomes lactic acid which can act as an enzyme inhibitor if too much builds up in cells. If oxygen is available, aerobic respiration will occur which involves all three stages of respiration. For this, the pyruvate molecules will be transported to the mitochondria which is an organelle adapted to maximise the rate of aerobic respiration. In the mitochondria, the matrix is a fluid with many enzymes. This is where the Krebs cycle will occur.

Pyruvate is converted into acetyl CoA which is cycled around producing energy carriers like NADH and ~~to~~ FADH.

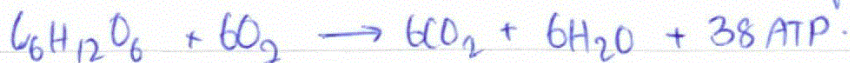
This produces an additional 2 ATP, and  $\text{CO}_2$  is released as a by-product.

Oxygen is required for this to occur. Then, the energy carriers are passed along a series of proteins on the cristae of the mitochondria, where 34 ATP are produced. This

final stage is called the electron transport chain. Here, cytochrome c oxidase joins  $\text{H}^+$  and  $\text{O}_2$  to form water which is also released as a by-product. Therefore, the equation for anaerobic respiration is:



Whereas the equation for aerobic respiration is:



This shows that aerobic respiration produces much more ATP from the complete break-down of glucose compared to anaerobic respiration which

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produces a small amount of ATP by only partially breaking down ~~the~~ glucose. However, anaerobic respiration does not require oxygen which is a limitation of the aerobic respiration system.

When mosquito larvae are at the surface of the water, they use a breathing tube to absorb high levels of oxygen so that they can carry out aerobic respiration. As larvae grow rapidly, they require large amounts of energy to facilitate this along with other life processes such as movement and metabolism.

When threatened, they retreat to the bottom of the pond where they rely on dissolved oxygen for aerobic respiration. If there is 100% dissolved oxygen, larvae will carry out aerobic respiration because there is a high concentration of oxygen for this process. This allows them to have a heart rate of 120 bpm, showing that the mosquito larvae <sup>are</sup> ~~have~~ producing plenty of oxygen so have a high cell respiration rate.

As the percentage of oxygen in the water decreases, the larvae heart rate decreases which shows a reduction in the amount of ATP being produced. This is because there is not enough oxygen for maximum rates of aerobic respiration, so the larvae also use anaerobic respiration to produce some ATP because it does not require oxygen.

When there is no oxygen available in the water (0% saturation) the larvae heart rate continues to beat 20 times each minute. This is significantly less than the 120 bpm when there was high oxygen availability. The reason larvae can continue contracting muscles in their hearts is because a small amount of energy/ATP is produced



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QUESTION  
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from anaerobic respiration. This is enough to keep them alive as it provides the heart muscle cells with some small amounts of ATP, but only enough for a slow heart rate of 20 bpm which would not allow for other processes like excessive movement.

The problem with this is that anaerobic respiration produces lactic acid as a by-product. This can be toxic to cells if it builds up because it can act as an enzyme inhibitor. After several hours of only carrying out anaerobic respiration, the lactic acid would accumulate in the cells, potentially causing cell death. It would also impact digestion and excretion for example because these processes require energy, which is only used to keep the larvae alive when they are under threat.

Therefore, it is not ideal to rely on anaerobic respiration for more than a short amount of time as a ~~defense mechanism~~ / safety method due to the build up of lactic ~~acid~~ acid and that only a limited amount of ATP is produced.



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91156



<b>Standard</b>	91156	<b>Display ID</b>	62223116	<b>Total score</b>	24
		<b>NSN</b>	139268924		
<b>Q</b>	<b>Grade score</b>	<b>Annotation</b>			
1	E8	<p>This is an example of a thorough discussion linking the products and reactants of the light-dependent and light independent phases of photosynthesis, linked to chloroplast structures and functions.</p> <p>Pg 3</p> <p>High surface area of thylakoids linked to light dependent reaction, linked to increased rate of reaction on the thylakoid membranes, linked to water being split into hydrogen and oxygen and purpose of chlorophyll.</p> <p>Pg4</p> <p>Role of stroma as a clear, enzyme-rich fluid explained linked to light passing through to the chlorophyll, linked to the products of the light dependent reaction used to allow carbon dioxide to be fixed into glucose.</p>			
2	E8	<p>This is an example of a full discussion of pH effects on enzyme activity and the role of co-factors.</p> <p>Pg 7</p> <p>Discussion of the role of co-factors binding to the active site, allowing the substrate to fit and the reaction to be effectively catalysed.</p> <p>Optimum range of activity and peak of pH 8 correctly identified. Denaturing explaining in terms of changes to the active site and no longer being able to fit the substrate.</p> <p>Pg 8</p> <p>Explains high and low points at which denaturing happens and enzyme activity happens, linked to the context and example give.</p>			
3	E8	<p>This is an example of a full discussion of respiration processes and effects, with multiple links to the resource material provided.</p> <p>Pg 11</p> <p>Aerobic respiration and anaerobic respiration explained fully.</p> <p>Pg 12</p>			



		<p>Aerobic respiration discussed in terms of ATP produced, lack of toxic by-products and linked to numbers from data table provided.</p> <p>Pg 13</p> <p>Effects of prolonged exposure to 0% oxygen linked to sustained use of anaerobic respiration linked to build up of lactic acid and limited supply of ATP.</p>
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